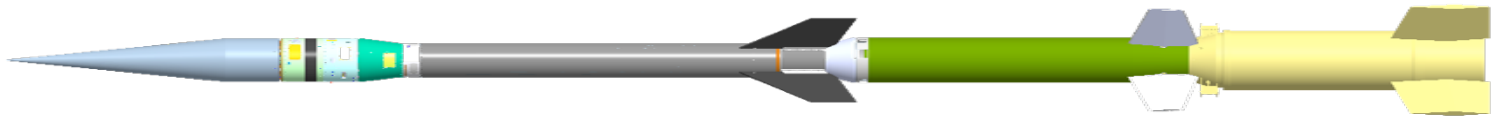
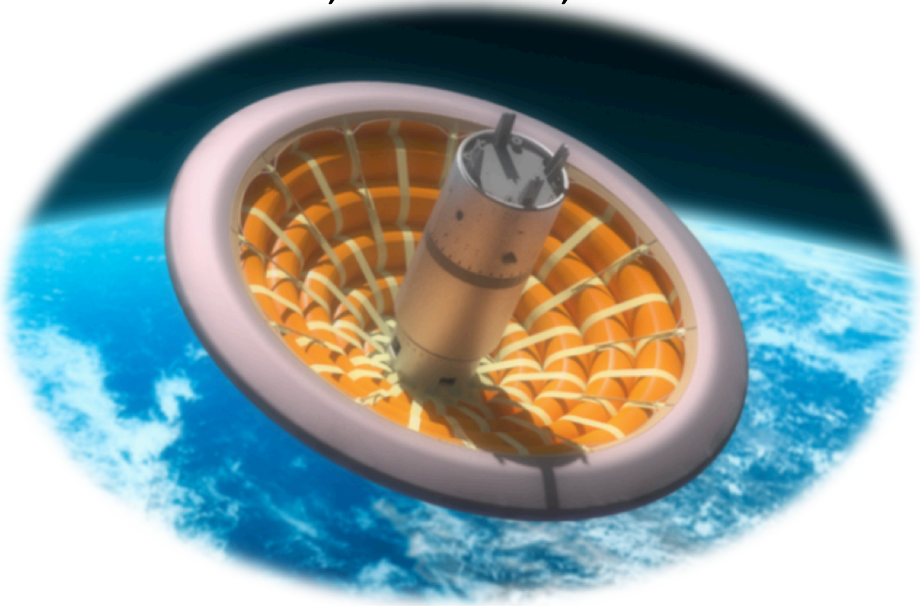


Planned Flight of the Inflatable Reentry Vehicle Experiment 3 (IRVE-3)

8th International Planetary Probe Workshop

Robert Dillman, Neil Cheatwood, Steve Hughes,
Joe Del Corso, RJ Bodkin, & Aaron Olds



Changes from IRVE-II to IRVE-3

IRVE-II Flew August 17, 2009

- 2-stage sounding rocket, 218km apogee; 125kg, 3m diameter RV saw 1.8W/cm^2
- Provided flight demonstration of aeroshell inflation and reentry stability
- Heat flux handled by 3 layers of Nextel fabric, no insulation

IRVE-3 Mission Objectives

- Demonstrate the reentry survivability of an inflatable aerodynamic decelerator with a flight relevant Thermal Protection System (TPS) in a flight environment with a peak reentry heat rate greater than 15 W/cm^2, and
- Demonstrate the effectiveness of an offset CG on the flight L/D of an inflatable aerodynamic decelerator.

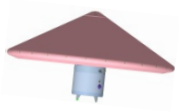
IRVE-II → IRVE-3 Upgrades

- 3-stage sounding rocket, 476km apogee
- Reentry vehicle mass more than doubled
- 3m inflatable, calculated flux ~18W/cm^2
- Flight relevant TPS with insulation layers
- Improved inflatable structure with thin-film bladders for lower gas leak rate
- Improved inflation system with re-closable valve replacing pyro valve
- Motorized CG-offset system for L/D
- ACS for 3-axis control prior to entry, roll control during entry
- Instrumented TPS on nose
- Improved sensors: 5 flux gauges & pressure taps on nose, IMU, GPS, 64 distributed thermocouples, & 4 cameras for 360° continuous video
- Launch late April 2012
- US Navy will attempt recovery

IRVE-3 Mission Concept

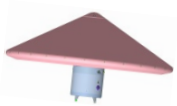
Apogee
366s, 476km

Coast…

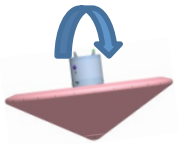


Start Aeroshell Inflation
478s, 423km (110s to 7.5psi)

Eject Nose Cone
132s, 242km



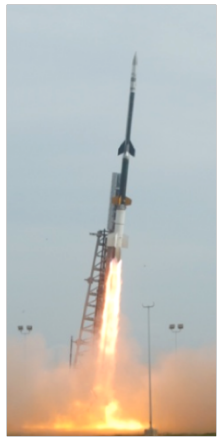
Actuate CG offset system
588s, 266km (1s duration)



Start ACS Reorientation
589s, 263km (60s duration)

NIACS damps rates
91s to 131s

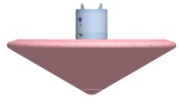
Separate RV & Nose Cone
From Brant & Transition
90s, 149km



Yo-Yo De-Spin, 80s
Brant Burnout, 56.9s
Brant Ignition, 23.0s
Taurus Separation 21.0s
Taurus Burnout, 18.5s
Taurus Ignition, 15.0s
Talos Burnout, 6.4s
Spin Motor Ignition, 0.9s
Leaves Rail, 0.5s
Talos Ignition, 0s

Launch on Black Brant-XI from WFF
940lb payload, El 84deg, Az 155deg

Atmospheric Interface, 25Pa (649s, ~80km)

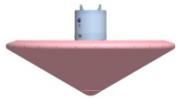


RV Peak Heat Rate 18W/cm^2
673s, 49km, Mach 7 (peak Mach 10.2)

RV Peak Dynamic Pressure 5035Pa
678s, 41km, 20.8g's

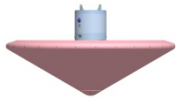
Reentry Experiment Complete at Mach < 0.7
(706s, 37km)

CG Offset Maneuvers



LOS by land radar & TM
15km altitude

Vent NIACS and Inflation System Gas



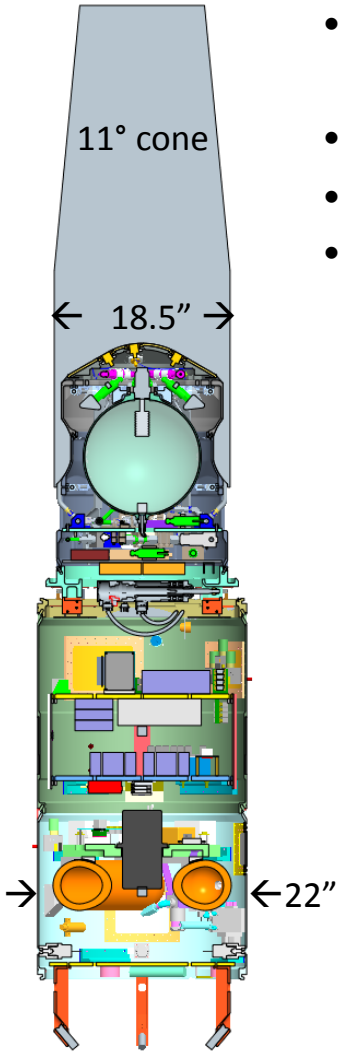
RV splashdown at 30m/s
383km downrange (1227s)

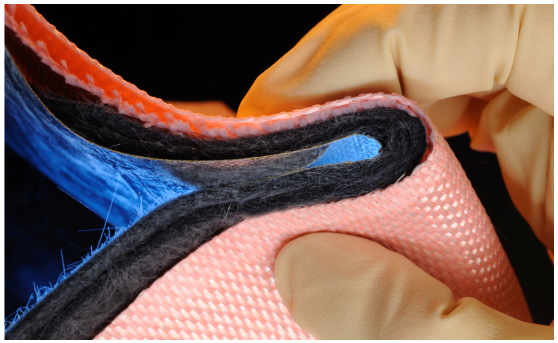
Attempt Recovery of RV

IRVE-3 Design Overview

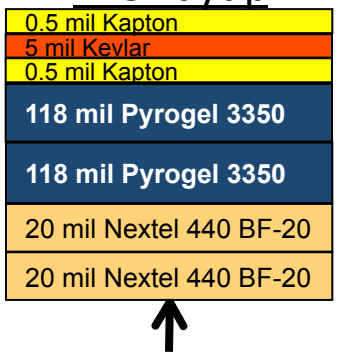
- 3m [118”] diam inflatable aeroshell with flexible TPS on forward surface
- Centerbody houses inflation system, CG offset mechanism, telemetry module, battery power systems, ACS, cameras
- Inflatable aeroshell packs to 18.5” diam inside nose cone for launch
  - 0.75” clearance on cylindrical portion, 0.375” on conical surface
- Restraint cover holds aeroshell for launch; pyrotechnic release in flight
- Inflation system fills aeroshell from 3000psi Nitrogen tank
- Attitude control system uses cold Argon thrusters to reorient for entry

Stowed (18.5”)



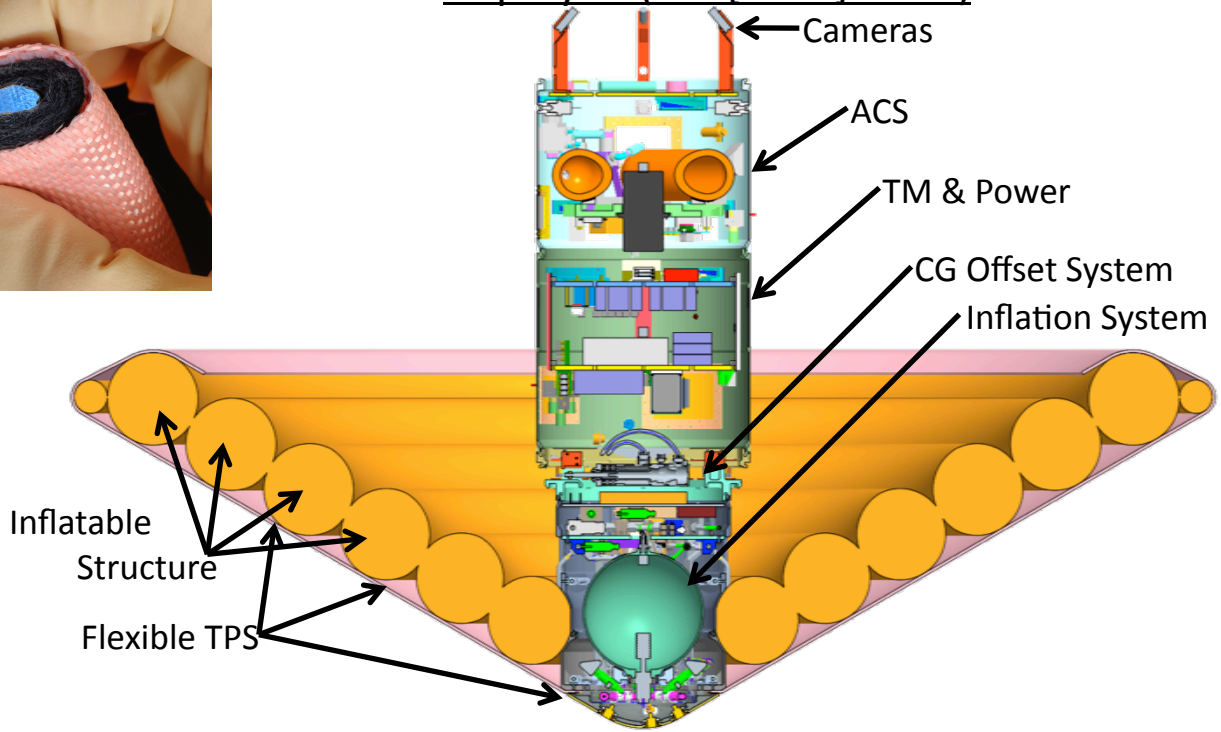


TPS Layup

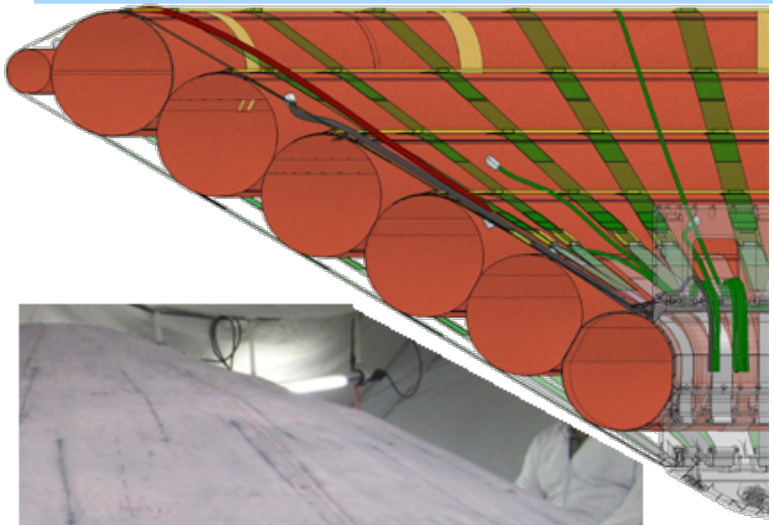


Aeroheating and Dynamic Pressure

Deployed (3m [118”] diam)



Inflatable Aeroshell

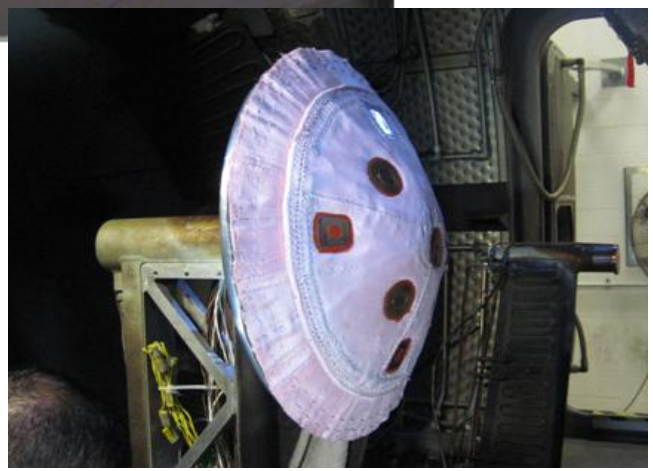


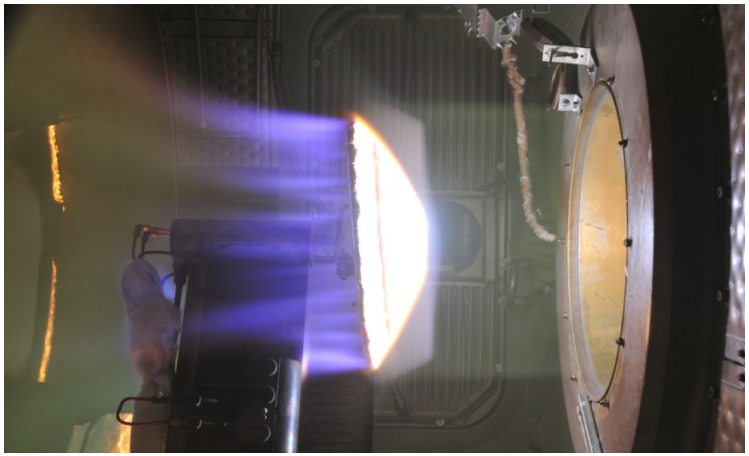
Inflatable Structure

- Toroids made from thin-film bladders covered by woven Kevlar sheathes
- Structural straps join bladders to each other and to RV centerbody
- Filled with nitrogen to nominal 10psig
- EDU1 tested, EDU2 under construction

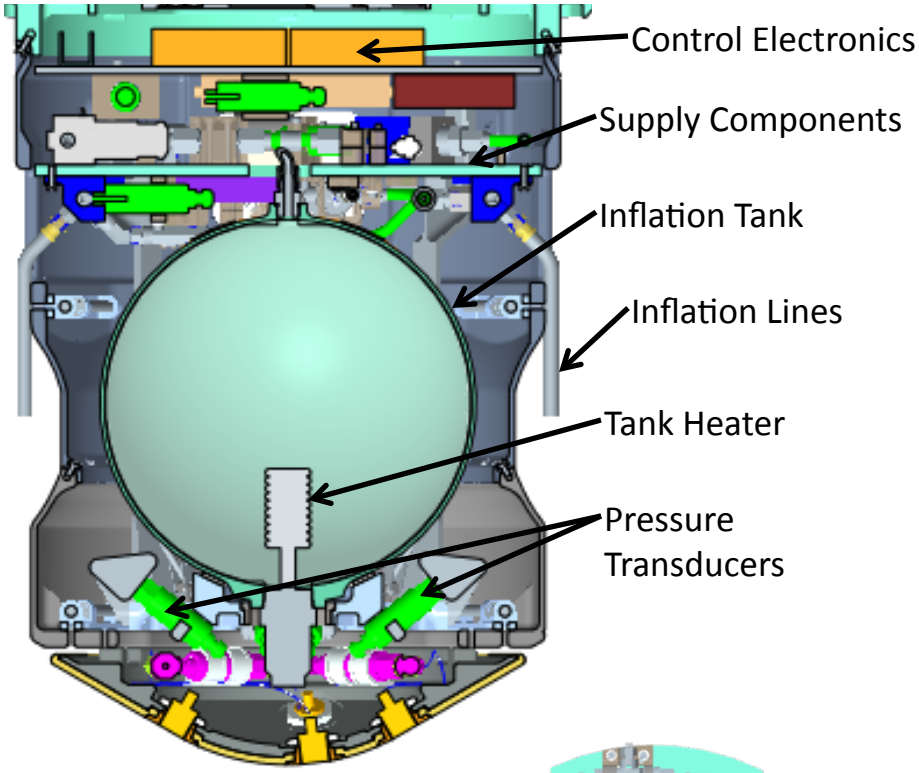
Thermal Protection System

- Multi-layer TPS defined in Langley SOW
- EDU fabricated, fit to inflatable structure
- Nose TPS EDU passed testing in JSC TP2
  - 10W/cm^2 and 20W/cm^2 full load; 30W/cm^2 for 5min

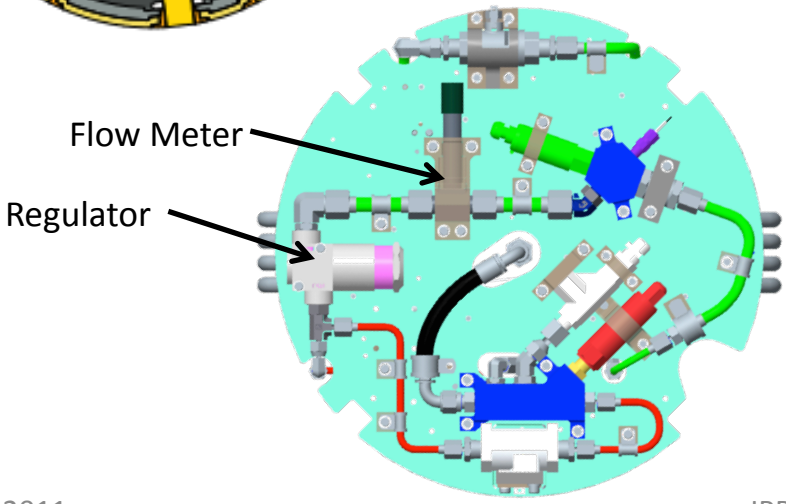


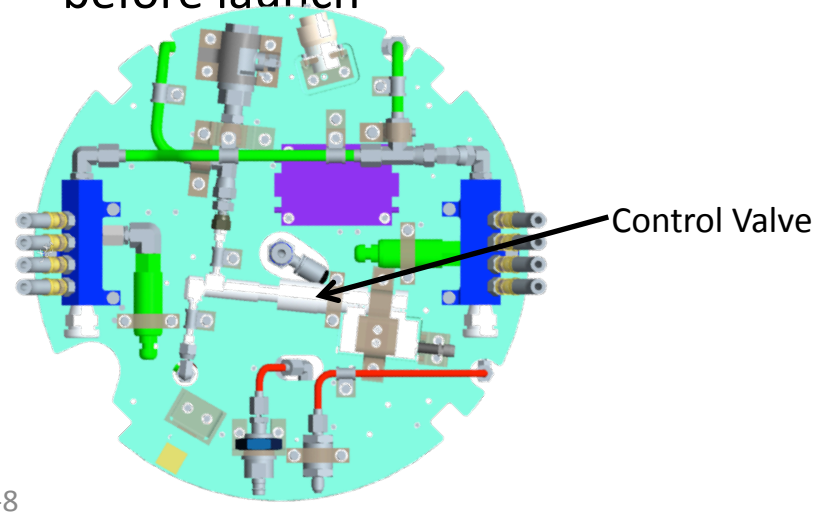


Inflation System



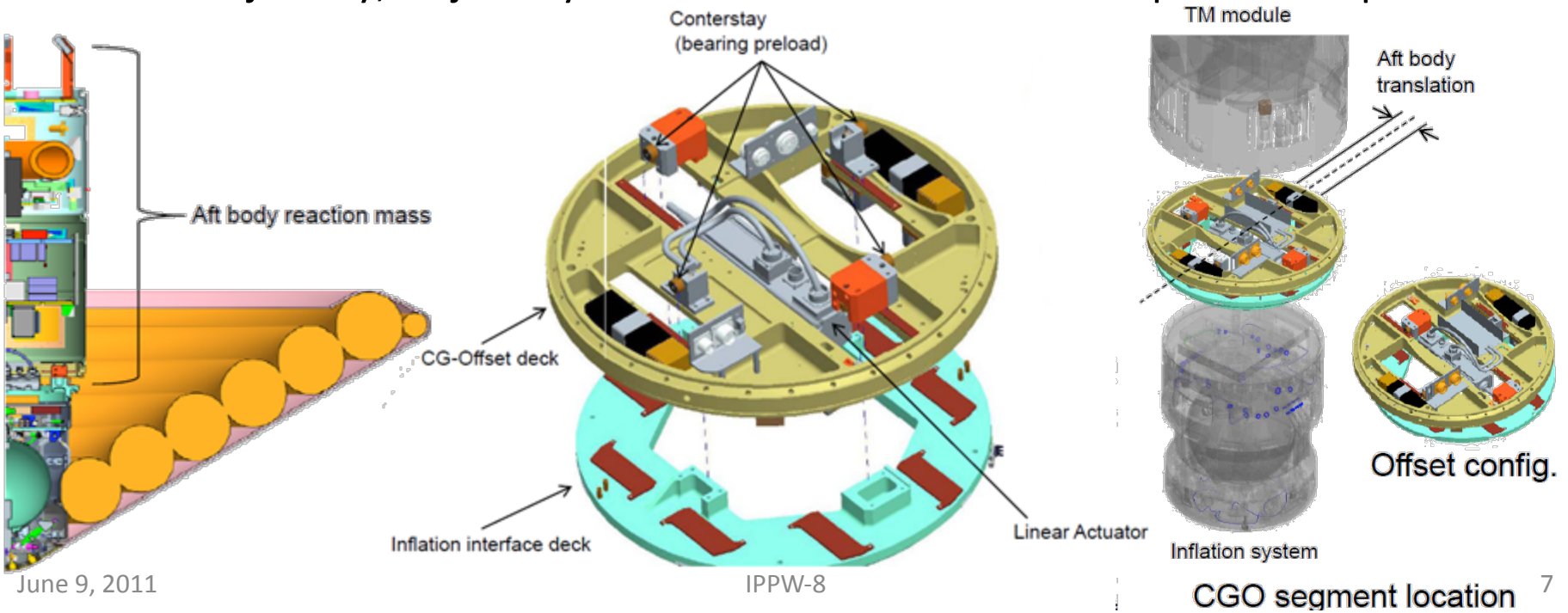
- Started by RV command timer
- 3000psi inflation tank supplies Nitrogen to aeroshell
- Control valve fills system to nominal 10psig; re-opens during descent to maintain pressure differential
- Analyzed with MSFC's GFSSP code
- System-level testing will verify time required to inflate EDU structure
- Full checkout in Langley complete system test in vacuum chamber before launch



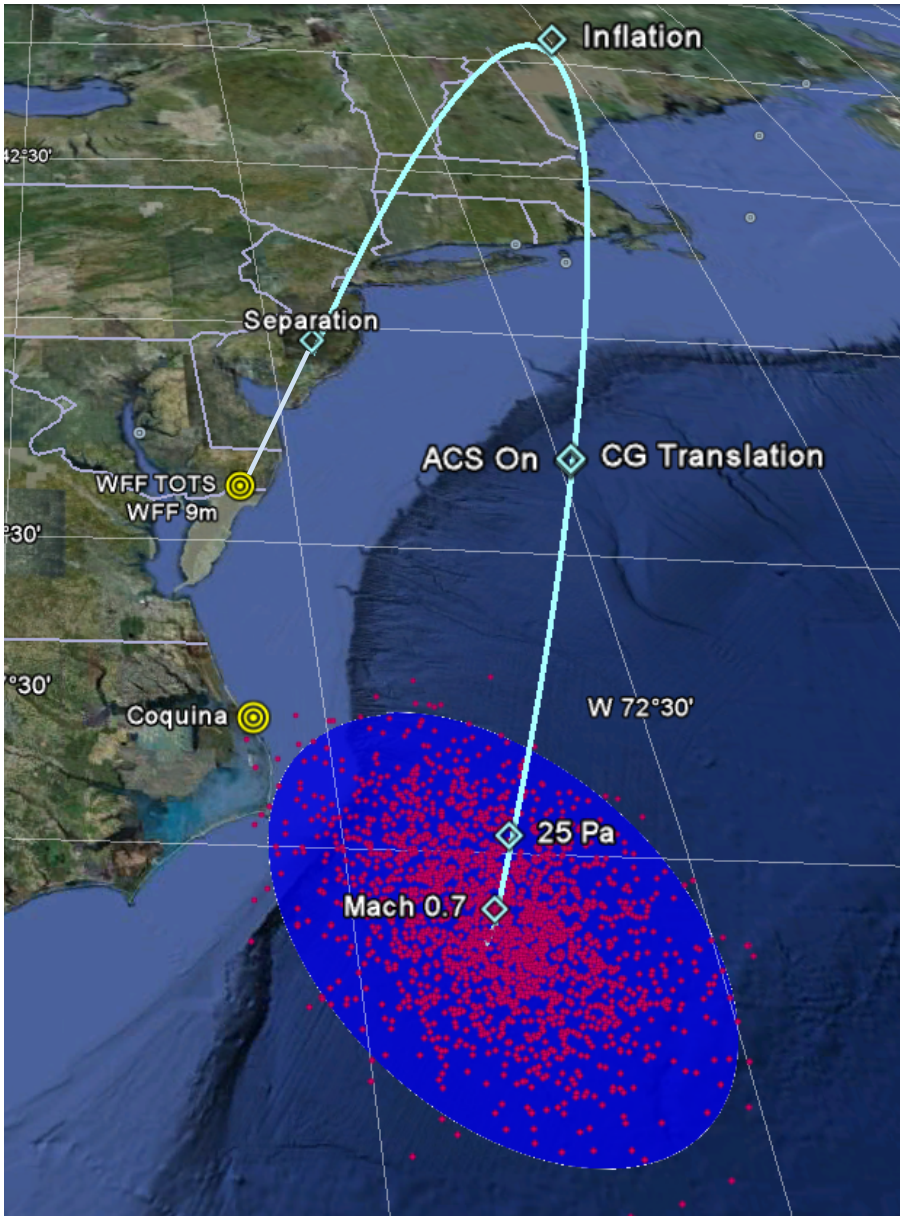


CG Offset System

- Motorized CGO shifts aft centerbody (TM, power, ACS) laterally relative to inflation system and aeroshell; transducers measure displacement
- EDU passed testing; flight unit tests will measure CG change with displacement
- CG will be centered for launch, and shifted after aeroshell inflation for L/D of 0.1
- ACS maintains roll angle of 0° during reentry for lift-up trajectory
- IMU, GPS, accelerometers, and ground radar provide trajectory data to evaluate L/D performance of inflatable aeroshell
- After reentry heat & pressure pulse, CGO shifts CG across RV centerline for lift-down trajectory; trajectory data will be used to evaluate speed of response



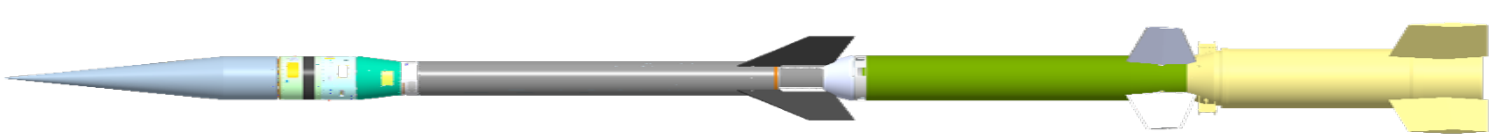
Splashdown and Recovery



- Splashdown 20min after launch
- With predicted aeroshell leak rate, inflation system will maintain pressure
- Splashdown at ~30m/s (67mph)
- Preliminary analysis indicates Kevlar structure should survive largely intact
- 3-sigma landing ellipse 269 x 367km
- RV will be tracked by WFF radars in Virginia and North Carolina
- All data broadcast to ground stations, including IMU and GPS locations
- US Navy will attempt to recover RV
- Dye marker packs included on RV to aid recovery

Remaining Work

- Continued updates of reentry trajectory & CFD
- Close out final design details
- Finish fabrication of centerbody hardware: inflation system, CG offset system, ACS, telemetry module
- Assembly and testing of centerbody hardware
- Testing of inflatable aeroshell structure EDU2
  - Pressure/load tests
  - Laser scan of geometry
  - Leak rate tests
  - Stiffness measurements
  - Deployment tests
- Update reentry analyses based on EDU2 stiffness
- Fabrication, assembly, and testing of flight aeroshell
- RV integration and complete system test in LaRC 16m vacuum chamber
- LV integration and testing at WFF
- Launch!
- Post-flight data analysis and aeroshell inspection



Questions?